

METHOD FOR MEASURING THE ABSOLUTE STEERING ANGLE OF STEERING SHAFT FOR VEHICLE

RELATED APPLICATIONS

5 The present disclosure relates to subject matter contained in priority Korean Application No. 10-2003-0079321, filed on November 11, 2003, which is herein expressly incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

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Field of the Invention

The present invention relates to a method for measuring an absolute steering angle of a steering shaft for a vehicle, more specifically, to a method for measuring an absolute steering angle of a steering shaft by using two rotatable bodies that rotate 15 together with the steering shaft at a predetermined rotation ratio.

Description of the Related Art

In general, measurement of an absolute steering angle of a steering shaft using an angle sensor only is known to be difficult because the measurement range is greater 20 than 360°.

Also the steering angle of the steering shaft should be immediately measured following start-up of a vehicle, regardless of an initial angular position. But the prior steering angle would not measured at present stage.

US Pat. Nos. 5,930,905 and 6,466,889B1 disclose a method for measuring an 25 absolute steering angle of a steering shaft based on rotational angular measurements of a

first rotatable body and a second rotatable body that rotate together with a steering shaft at a predetermined rotation ratio.

In the disclosures, the absolute rotation angle of the first rotatable body and of the second rotatable body are expressed by $\Psi = \Psi' + i\Omega$ and $\theta = \theta' + j\Omega$, respectively

5 (wherein, Ω indicates a measurement range of an angle sensor measuring the Ψ' and the θ' ; i is a whole number representing the number of times when the first rotatably body's absolute rotation angle Ψ is greater than the Ω , i.e. a frequency of the first rotatable body; and j is a frequency of the second rotatable body), and the absolute steering angle, Φ , can be obtained through a specific calculation procedure using measurements of Ψ'

10 and θ' .

According to the US Pat. No. 5,930,905, the measurements of Ψ' and θ' are substituted to the following equation (1), which is derived from a geometrical relation among Ψ , θ , and Φ to get k , and by rounding off k , a whole number k is obtained. Then the k , Ψ' and θ' are substituted to the following equation (2) to obtain Φ .

15 <Equation 1>

$$k = \{(m+1)\Theta' - m\Psi'\} / \Omega$$

<Equation 2>

$$\Phi = \{m\Psi' + (m+1)\Theta' - (2m+1)k\Omega\} / 2n$$

20 (Here, m indicates the number of gear teeth of the first rotatable body; $m+1$ indicates the number of gear teeth of the second rotatable body; and n indicates the number of gear teeth formed on the steering shaft engaged with the first and second rotatable bodies.)

On the other hand, according to the US Pat. No. 6,466,889B1, the steering angle, Φ , can be obtained directly from a relation between the difference of absolute rotation angles of two rotatably bodies, $\Psi - \theta$, and 'i' of the first rotatable body (or the

second rotatable body). Here, $\Psi - \theta$ is obtained by adding Ω to a measurement of $\Psi' - \theta'$ if the measurement is a negative value, or by applying a measurement of $\Psi' - \theta'$ if the measurement is not a negative value. The 'i' is calculated from the relation between $\Psi - \theta$, and i, and Ψ is calculated from the known values of Ψ' and i. Based 5 on these values, the absolute steering angle of a steering shaft, Φ , is obtained.

When 'i' becomes k_1 as the steering shaft is rotated with maximal, the rotation angle difference $\Psi - \theta$ should be equal or less than the measurement range of the angle sensor, namely Ω (cf. in the US Pat. No. 6,466,889B1, $\Psi - \theta$ is set to be equal to Ω). In other words, the rotation angle difference $\Psi - \theta$ successively varies from 0° to Ω 10 until the steering shaft is rotated with maximal, and i-value varies step by step from 0 to k_1 .

In particular, the US Pat. No. 6,466,889B1 made an assumption that $\Psi - \theta$ and i-value are in a linearly proportional relation with each other, meaning that the value for i successively varies from 0 to k_1 as the rotation angle difference $\Psi - \theta$ successively 15 varies from 0° to Ω . Also, the value of 'i' is obtained by taking a maximum whole number that is smaller than a value obtained from the multiplication of $\Psi - \theta$ measured value and k_1/Ω . For example, if $\Psi - \theta$ times k_1/Ω is 5.9, i is 5.

However, the above method poses a problem that 'i - j' has to be either 0 or 1 and should not be greater than 2 because a maximum value of $\Psi - \theta$ cannot be greater 20 than Ω .

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a method for measuring an absolute steering angle of a steering shaft rotating by more than 360 25 degrees, to reduce measurement errors and to simplify a calculation procedure.

Another object of the present invention is to provide a method for measuring an absolute steering angle using one single rotatable body, in which the rotatable body includes a memory means for storing an i-value.

Still another object of the present invention is to provide a method for 5 measuring an absolute steering angle of a steering shaft to obtain a frequency of a first rotatable body, i, or a frequency of a second rotatable body, j, without using $\Psi - \theta$, and obtain the absolute steering angle with simplified calculation, as once the i-value or the j-value is obtained.

As for the method for measuring the steering angle of the steering shaft for a 10 vehicle, a first rotatable body that rotates together with the steering shaft at a predetermined ratio is used. When needed, a second rotatable body that rotates together with the steering shaft at a predetermined ratio can also be used.

An absolute rotational angle of the first rotatable body, Ψ , can be expressed as $\Psi' + i\Omega$, and an absolute rotational angle of the second rotatable body, θ , can be 15 expressed as $\theta' + j\Omega$. Ψ' and θ' are measured by means of an angle sensor. Here, Ω represents the measurement ranges of the angle sensors for measuring Ψ' and θ' , i is a whole number that represents a frequency of the first rotatable body indicating the number of times the first rotatable body rotates over Ω (for example, if Ψ is 380° in the case that Ω is 180°, then i is 2), and j is a frequency of the second rotatable body. In 20 other words, the absolute rotational angle of the first rotatable body, Ψ , can be expressed by $\Psi' + i\Omega$, wherein Ψ' is a relative rotational angle measured by the angle sensor whose measurement range is Ω . The absolute rotational angle of the second rotatable body, θ , can be expressed in the same manner.

The measurement range of the angle sensor, Ω , can be 180° or 360° or a 25 different degree. Either contact angle sensors or non-contact angle sensors can be

utilized as long as the angle sensors are suitable for the measurement of Ψ' and θ' .

In the present invention, the absolute steering angle Φ of the steering shaft is measured by using the first rotatable body. In order to measure a successive present Φ value after measuring a previous Φ value of the steering shaft, an angle sensor whose measurement range is Ω is used to measure a relative rotational angle Ψ' of the first rotatable body to obtain its measurement value Ψ_M' . By comparing a present Ψ_M' value to a previous Ψ_M' value, a present i-value, which is a frequency of the first rotatable body, is determined from a previous i-value. Then the present Ψ_M' value and the present i-value are used to obtain an absolute rotational angle of the first rotatable body, i.e. a present Ψ value, and from this present value for the absolute rotational angle, a present value of the absolute steering angle Φ of the steering shaft is obtained (hereinafter, the resulting Φ is called Φ_1).

To measure the present value of the absolute steering angle Φ , a previous value for the frequency i of the first rotatable body should be determined first. That is, to obtain the absolute steering angle Φ from the present i-value for the first rotatable body as suggested by the present invention, it would be necessary to prepare a method for obtaining or defining the previous i-value first.

There could be diverse methods for determining the i-value. As an example, the i-value could be stored in a memory and read out later. When the memory is used, it is possible to measure the absolute steering angle using only one rotatable body like the first rotatable body.

Meanwhile, without using the memory means, an i-value can also be determined by utilizing a second rotatable body that rotates together with the steering shaft at a predetermined rotation ratio. In other words, the angle sensors, whose measurement ranges are Ω s, are used to get Ψ' and θ' measurements, i.e. Ψ_M' and θ_M' .

Then, based on a relation between Ψ' and θ' , a plurality of θ' 's corresponding to the Ψ'_M is calculated to obtain their calculation values θ_C' . By comparing the plurality of θ_C' to the θ_M' , a frequency of the first rotatable body, i , is obtained. Further details on this method will be provided later.

5 When the previous i -value is determined through the above procedure, the relative rotational angle Ψ' of the first rotatable body is measured by using the angle sensor whose measurement range is Ω . To obtain a present i -value, 1 is added/subtracted to/from the previous i -value, based on a comparison result of a previous Ψ'_M value to a present Ψ'_M value. The reason for that is when the i -value is
10 increased by as much as 1, the value of Ψ'_M varies from Ω to 0, and when the i -value is decreased by as much as 1, the value of Ψ'_M varies from 0 to Ω . That is to say, Ψ'_M varies a lot before and after a variation of the i -value. The above procedure is useful not only for simplifying the calculation procedure, but also for freeing the influence of a measurement error included in θ_M' upon the i -value.

15 When a secondary rotatable body is additionally used, the frequency j of the second rotatable body is determined using the same method described above. Afterwards, by comparing a present θ_M' value to a previous θ_M' value, 1 is added/subtracted to/from the previous j -value, resulting in a present j -value. From the present j -value, the present value for the absolute steering angle Φ is obtained
20 (hereinafter, the resulting Φ is called Φ_2). Finally, the mean value of the Φ_1 and the Φ_2 is taken for the absolute steering angle, Φ , of the steering shaft. By taking the mean value, the measurement errors included in Ψ'_M and θ_M' can be cancelled out.

BRIEF DESCRIPTION OF THE DRAWINGS

25 The above objects, features and advantages of the present invention will

become more apparent from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 illustrates a preferred embodiment of the present invention;

Fig. 2 graphically illustrates a relation between Ψ' and θ' in accordance with a 5 steering angle of a steering shaft;

Fig. 3 illustrates a calculation procedure to obtain ϕ_1 according to the present invention; and

Fig. 4 illustrates a simplified calculation procedure for obtaining 'i' according to the present invention.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will be described herein below with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail since they would obscure 15 the invention in unnecessary detail.

Fig. 1 shows a first rotatable body 2 and a second rotatable body 3 being engaged with a steering shaft 1, angle sensors 4 and 5 for measuring relative rotation angles Ψ' and θ' of the first and second rotatable bodies, and an operational circuit 6 for conducting a designated operation using Ψ'_M and θ'_M measurements provided by the 20 sensors 4 and 5 and for outputting a resulting Φ . Here, a rotation ratio (r1) of the steering shaft to the first rotatable body is 7/4, and a rotation ratio (r2) of the steering shaft to the second rotatable body is 6.5/4 (the numbers of the teeth of the gears represented in Fig. 1 may not be correct). Fig. 2 graphically shows the relation between the relative rotation angle (Ψ') of the first rotatable body and a relative rotation angle (θ') of the second rotatable body during 4 rotations of the steering shaft. In Fig. 25

2, x-axis denotes the steering angle Φ , and Ω is 180° . Fig. 3 illustrates the procedure for obtaining the absolute steering angle, Φ , of the steering shaft, based on measurements of the Ψ' and the θ' .

5 Preferably, the relation between the relative rotation angles of the first and second rotatable bodies as shown Fig. 2 is obtained experimentally by measuring the relative rotation angle (ψ') of the first rotatable body and the relative rotation angle (θ') of the second rotatable body, as varying the steering angle of the steering shaft.

10 As shown in Fig. 3, ψ_M' and θ_M' are measured by employing angle sensors. Then by taking advantage of the relation shown Fig. 2, a plurality of θ_C 's corresponding the ψ_M' are calculated (θ_{Ci}' in Fig. 3 indicates θ_C 's corresponding to 'i'). Then the closest value among the θ_C 's to θ_M' is found to get i. For instance, suppose that $\Psi_M' = 130^\circ$, and $\theta_M' = 105^\circ$. As shown on the graph of Fig. 2, when $\Psi' = 130^\circ$, its corresponding θ_C 's, given that i ranges from 0 to 13, are $120.7^\circ, 107.9^\circ, 95^\circ, 82.1^\circ, 69.3^\circ, 56.4^\circ, 43.6^\circ, 30.7^\circ, 17.9^\circ, 5^\circ, 172.1^\circ, 159.3^\circ, 146.4^\circ$, and 133.6° , successively. Among 15 these values for θ_C 's, 107.9° is the closest value to the θ_M 's, which is 105° , so the corresponding i becomes 1.

Using the known i-value and Ψ_M' values, the steering angle, Φ_1 , of the steering shaft can be calculated applying the following equation 5.

<Equation 5>

20
$$\Phi_1 = 1/r_1 (\Psi_M' + i\Omega) = 4/7 (130^\circ + 180^\circ) = 177^\circ.$$

Once the i-value is determined, a present Ψ_M' value is compared to a previous Ψ_M' value, and based on the comparison result, 1 is added/subtracted to/from a previous i-value. For example, if $\Delta\Psi_M'$ (i.e. the present Ψ_M' value – the previous Ψ_M' value) is smaller than a specific negative value, add 1 to the previous i-value, and if $\Delta\Psi_M'$ 25 larger than the specific positive value, subtract 1 from the previous i-value, if $\Delta\Psi_M'$

belongs to neither case, the previous i-value is maintained as the present i-value.

The above procedure is well illustrated in Fig. 4. As shown in Fig. 4, if $\Delta\Psi_M'$ is smaller than a specific value, say, $-A_s$, 1 is added to the previous i-value, and if $\Delta\Psi_M'$ is larger than A_s , 1 is subtracted from the previous i-value, and in neither case, the 5 present i-value maintains the present i-value. For instance, suppose that the previous i-value is 3, the specific value A_s is 170° , the previous Ψ_M' value is 179° , and the present Ψ_M' value is 1° . Then the $\Delta\Psi_M'$ equals to -178° , which is smaller than -170° , so the present i-value becomes 4. On the other hand, if the previous Ψ_M' value is 1° and the present Ψ_M' value is 179° , the $\Delta\Psi_M'$ equals to 178° , which is larger than 170° , so the 10 present i-value becomes 2.

Once the present i-value is obtained, the resulting i-value and the present Ψ_M' value are substituted to the equation 5 to obtain the present $\Phi 1$.

Similar to the method for obtaining the i-value by calculating the plurality of θ_C 's from the Ψ_M' value, a j-value also can be obtained by calculating a plurality of Ψ_C 's 15 from the θ_M' . Then a successive present j-value can be obtained by comparing a present θ_M' value to a previous θ_M' value. Using these known values, the steering angle, $\Phi 2$, of the steering shaft can be obtained applying the following equation 6.

<Equation 6>

$$\Phi 2 = 1/r^2 (\theta_M' + j\Omega)$$

20 Preferably, the mean value of the $\Phi 1$ and $\Phi 2$ is used to define the steering angle of the steering shaft. By taking the mean value, it is possible to minimize measurement errors in Ψ_M' and θ_M' values.

In conclusion, according to the present invention, the steering angle can be obtained directly from the i-value and the j-value, without using $\Psi-\theta$. Once the i- 25 value and the j-value are obtained, the following calculation procedure is much

simplified.

In other words, once the i-value is obtained, a successive i-value can be obtained simply by comparing the present Ψ_M' value to the previous Ψ_M' value. More importantly, when the second rotatable body is additionally used, the i-value is no 5 longer under the influence of measurement error included in the θ_M' value. Moreover, although the θ_M' value may not be measured because of a mechanical trouble in the angle sensor, the steering angle for the steering shaft can still be measured.

In addition, the present invention can reduce calculation errors found in rounding off steps to define the absolute steering angle (e.g., rounding off 'k'-value in 10 US Pat. No. 5,930,905 or rounding off 'i'-value in US Pat. No. 6,466,889B1). That is, the present invention can resolve a serious error (± 1) in the rounding off of the absolute steering angle.

Further, the memory means for storing an i-value makes it possible to measure the absolute steering angle using one single rotatable body.

15 While the invention has been described in conjunction with various embodiments, they are illustrative only. Accordingly, many alternative, modifications and variations will be apparent to persons skilled in the art in light of the foregoing detailed description. The foregoing description is intended to embrace all such alternatives and variations falling with the spirit and broad scope of the appended claims.